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Fourche Creek Urban Runoff Project
Volume 1. Summary Report

METROPLAN, Little Rock, AR

Prepared for

Environmental Protection Agency, Washington, DC

1983

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The Little Rock, AK, WQM plan identified urban runoff into Fourche Creek as the most significant nonpoint source water quality problem in the metropolitan area. Project objectives include, (1) clarifying the nature and extent of the problem; (2) analysis of the effectiveness of selected best management practices; (3) assessing cost effectiveness of BMP's, and (4) effects of application of BMP's throughout the Fourche Creek System.

BMP's evaluated included gabions, channel clearing with bank relocation and rip rap, and vegetation, and use of sodding with check dams to reduce slopes.

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Soil Erosion
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Sediments
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FOURCHE CREEK URBAN RUNOFF PROJECT

VOLUME I

SUMMARY REPORT

METROPLAN

A Council of Local Governments

1983

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FOURCHE CREEK URBAN RUNOFF PROJECT

Volume I: Summary Report

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FOURCHE CREEK URBAN RUNOFF PROJECT

SUMMARY

Background and Initial Assumptions

Fourche Creek and its branches constitute an important stream system in the Little Rock Metropolitan Area. The main stem of the Fourche crosses Little Rock from west to east. Together with its major branches the Fourche drains ninety per cent of the urban area, discharging the accumulated waters into the Arkansas River at a single point east of the city. Thus, the Fourche system presented an ideal study area for determining the impact of urban runoff on water quality in a realistic and relatively easily controlled situation. As the Fourche enters the urban area it is a stream dominated by rural runoff. Once inside the metropolitan area, stream water quality comes under the impact of several types of urban pollutants and the Fourche has been classified water quality limited. These pollutants are nonpoint in origin.

Problem Definition

The Little Rock Water Quality Management plan (Section 208) named urban runoff into the Fourche as the most significant non-point source water quality problem in the metropolitan area. Projections made in the 208 planning process predicted urban loads in the Fourche system to increase through the year 2000. (See Summary Exhibit 1.) Water quality problems in the Fourche urban

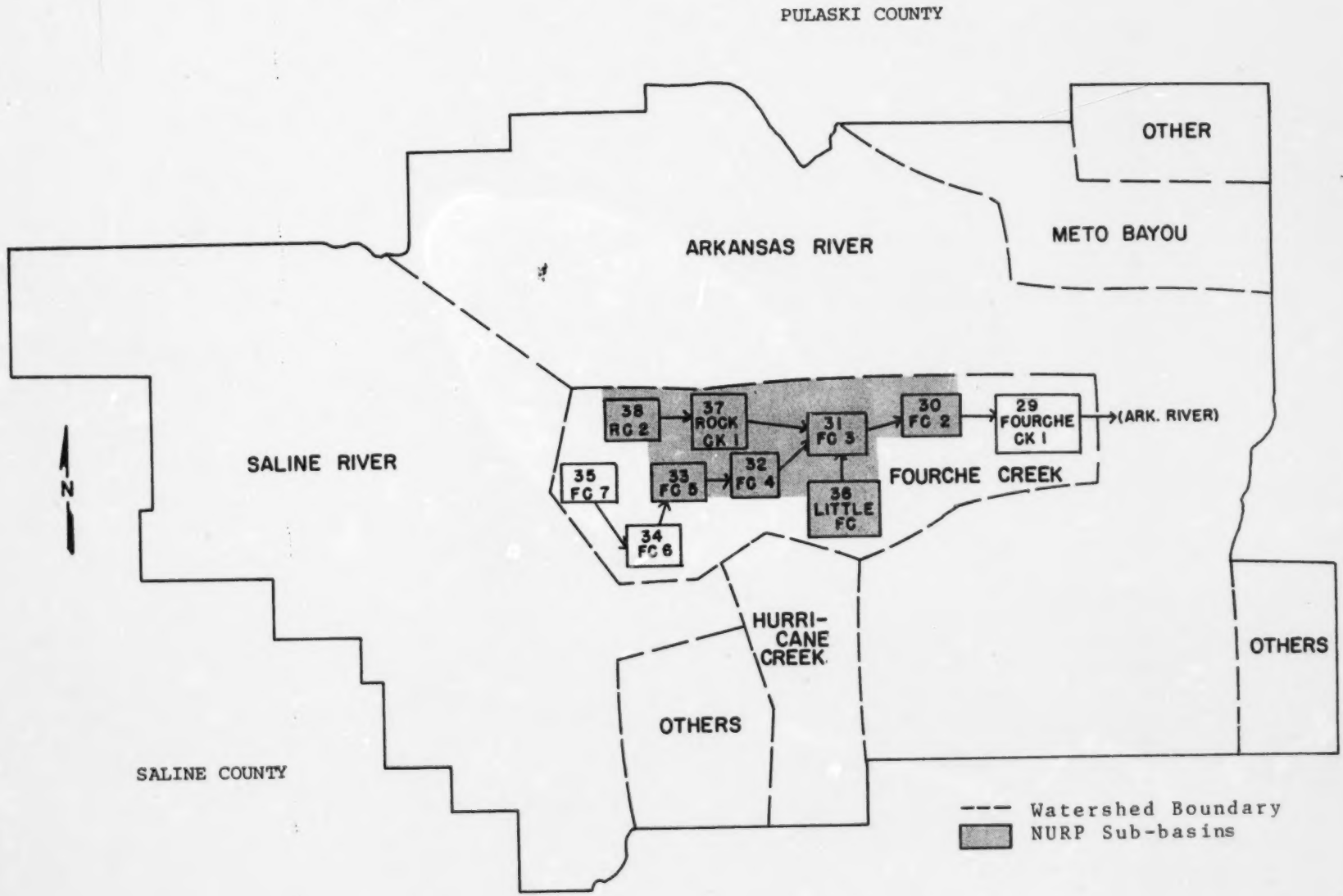

Exhibit 1-A PULASKI-SALINE COUNTIES WATERSHEDS

Actual 1977

WATERSHED NAME	TOTAL AREA (acres)	% URBAN	URBAN AREA (acres)	FRACTION URBAN IMPERV.	RUNOFF-TO-RAINFALL RATIO, R_v	ANNUAL RUNOFF (10^6 ft^3/yr)	ANNUAL URBAN POLLUTANT LOADS			
							BOD_5 (lb/yr)	TN (lb/yr)	TP (lb/yr)	SEDIMENT (10^3 lb/yr)
Fourche Creek 1	3,884	42	1,627	0.439	0.38	111	62,700	27,700	2,070	1,245
Fourche Creek 2	4,812	49	2,345	0.494	0.40	168	94,200	41,900	3,140	1,884
Fourche Creek 3	5,822	76	4,447	0.452	0.39	308	172,900	76,800	5,760	3,454
Fourche Creek 4	10,184	27	2,793	0.372	0.36	182	102,000	45,400	3,400	2,041
Fourche Creek 5	14,830	26	3,920	0.386	0.37	258	144,600	64,300	4,826	2,893
Fourche Creek 6	10,992	15	1,703	0.401	0.37	113	61,200	28,200	2,110	1,267
Fourche Creek 7	20,896	11	2,242	0.392	0.37	148	83,100	36,900	2,770	1,660
Little Fourche Creek	16,758	25	4,237	0.511	0.41	312	175,100	77,800	5,830	3,499
Rock Creek 1	7,300	59	4,329	0.444	0.38	298	167,400	74,300	5,570	3,342
Rock Creek 2	10,000	22	2,153	0.284	0.34	130	72,800	32,400	2,430	1,458
TOTAL	105,478	28	29,796	0.427	0.38	2,028	1,136,000	505,700	37,900	22,743

Projected 1983

WATERSHED NAME	TOTAL AREA (acres)	% URBAN	URBAN AREA (acres)	FRACTION URBAN IMPERV.	RUNOFF-TO-RAINFALL RATIO, R_v	ANNUAL RUNOFF (10^6 ft^3/yr)	ANNUAL URBAN POLLUTANT LOADS			
							BOD_5 (lb/yr)	TN (lb/yr)	TP (lb/yr)	SEDIMENT (10^3 lb/yr)
Fourche Creek 1	3,884	46	1,797	0.413	0.37	121	68,100	30,200	2,260	1,357
Fourche Creek 2	4,812	49	2,370	0.495	0.40	170	95,100	42,400	3,180	1,906
Fourche Creek 3	5,822	78	4,522	0.452	0.39	314	175,900	78,200	5,870	3,521
Fourche Creek 4	10,184	29	2,967	0.377	0.36	194	108,700	48,300	3,630	2,176
Fourche Creek 5	14,830	28	4,203	0.391	0.37	278	155,700	69,300	5,200	3,117
Fourche Creek 6	10,992	17	1,842	0.403	0.37	123	68,900	30,700	2,300	1,379
Fourche Creek 7	20,896	12	2,490	0.408	0.37	167	93,400	41,600	3,120	1,873
Little Fourche Creek	16,758	27	4,564	0.510	0.41	336	188,100	83,700	6,280	3,768
Rock Creek 1	7,300	65	4,753	0.448	0.38	329	184,600	82,000	6,150	3,689
Rock Creek 2	10,000	23	2,260	0.289	0.34	137	77,000	34,100	2,560	1,536
TOTAL	105,478	30	31,768	0.431	0.38	2,169	1,215,500	540,500	40,550	24,322

Projected 2000

WATERSHED NAME	TOTAL AREA (acres)	% URBAN	URBAN AREA (acres)	FRACTION URBAN IMPERV.	RUNOFF-TO-RAINFALL RATIO, R_v	ANNUAL RUNOFF (10^6 ft^3/yr)	ANNUAL URBAN POLLUTANT LOADS			
							BOD_5 (lb/yr)	TN (lb/yr)	TP (lb/yr)	SEDIMENT (10^3 lb/yr)
Fourche Creek 1	3,884	48	1,877	0.429	0.38	128	71,700	31,900	2,390	1,435
Fourche Creek 2	4,812	50	2,392	0.498	0.40	172	96,500	42,900	3,210	1,929
Fourche Creek 3	5,822	79	4,579	0.554	0.45	370	207,400	92,200	6,910	4,149
Fourche Creek 4	10,184	37	3,776	0.397	0.37	251	140,700	62,500	4,690	2,815
Fourche Creek 5	14,830	37	5,426	0.405	0.37	363	203,800	90,500	6,780	4,071
Fourche Creek 6	10,992	22	2,408	0.420	0.38	163	91,100	40,600	3,050	1,828
Fourche Creek 7	20,896	16	3,370	0.430	0.38	230	128,600	57,300	4,300	2,579
Little Fourche Creek	16,758	34	5,742	0.506	0.41	419	235,200	104,400	7,830	4,699
Rock Creek 1	7,300	72	5,275	0.451	0.39	366	205,200	91,200	6,840	4,104
Rock Creek 2	10,000	28	2,797	0.325	0.35	175	98,100	43,600	3,270	1,962
TOTAL	105,478	36	37,642	0.464	0.39	2,637	1,478,300	657,100	49,270	29,571

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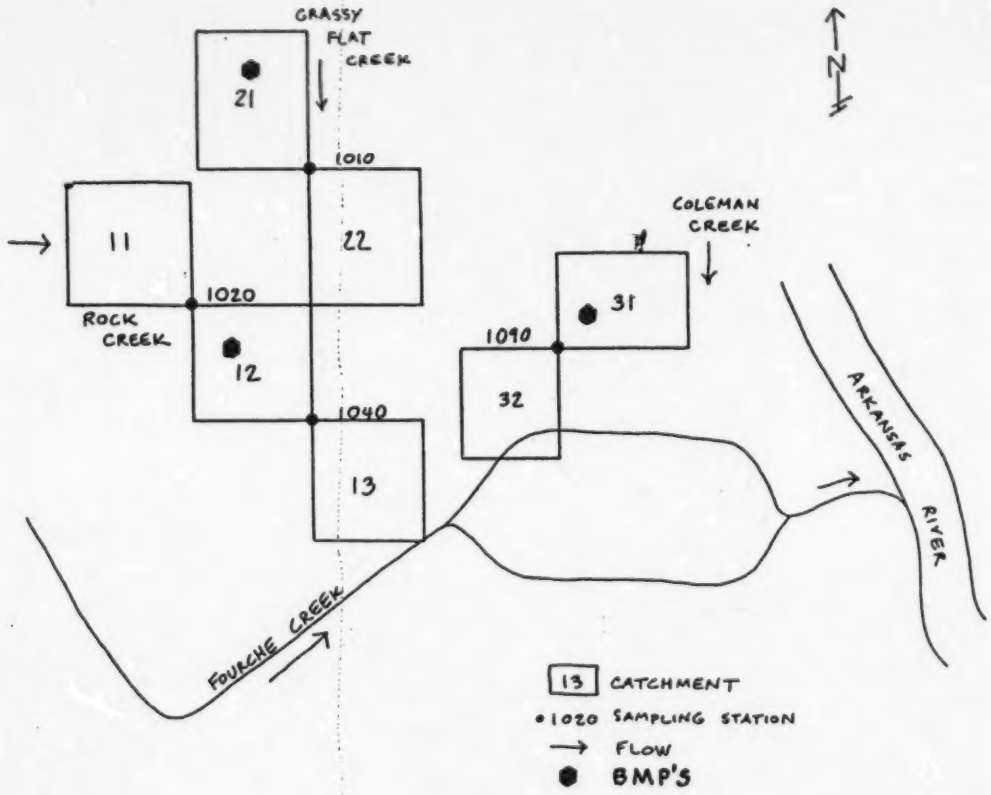
URBAN RUNOFF, FOURCHE CREEK BASIN
Exhibit 1-B

watersheds identified in the earlier plan included excessive fecal and total coliform concentrations, low pH, phosphorous, and heavy metals contamination in addition to more typical conditions such as low dissolved oxygen (DO), and elevated concentrations of suspended solids. Coliform standards are routinely violated. Sources of many of these pollutants were also isolated during the planning: overflowing and leaking sewers, construction projects on roads and in subdivisions, and an unstabilized urban drainage system. These conditions prevent full utilization of the Little Rock Park system through which Fourche Creek and its major tributaries flow.

Project Proposal

Building on the foundation of the 208 plan, the Fourche Creek Urban Runoff Project objectives were briefly, (1) to clarify the nature and extent of the Fourche Creek pollution problems including sources and transport mechanisms; (2) to analyze one or two Best Management Proactices selected to control urban runoff and evaluate their effectiveness in small watersheds, (3) to assess the cost effectiveness of these BMP's if demonstrated to be technically effective, and (4) to estimate the beneficial community impacts if the cost effective BMP's were applied throughout the Fourche Creek System.



POPULATION ESTIMATES IN
NURP BASINS AND SUB-BASINS-1980

Rock Creek

Sub-basin	11	537
" "	12	22,875
" "	13	2,789
	Total	26,201

Grassy Flat

Sub-basin	21	12,840
" "	22	3,516
" "	Total	16,356

Coleman

Sub-basin	31	10,624
" "	32	89
	Total	10,713

GRAND TOTAL NURP BASINS--53,270

Exhibit 2: NURP Project Sub-basins, BMP's, and Populations

FAST TRAK FIXED SITE DATA

PROJECT AR

Sub-Basin	Station Code	Total Area (Acres)	Residential Land Use (Per Cent)	Commercial Land Use (Per Cent)	Industrial Land Use (Per Cent)	Open Land Use (Per Cent)	Other Land Use (Per Cent)	Population Density (/Acre)	Slope (Ft/Mile)	Impervious Area (Per Cent)
11	1020	5187.2	8.4	0.7	2.2	.06	88.7	.10	94.28	32.8
12	1040	4816.08	48.9	9.8	4.0	2.45	34.8	4.75	26.83	50.7
13	-	712.00	35.6	27.2	3.1	7.81	26.2	3.92	15.62	53.9
21	1010	2460.8	61.6	10.4	4.7	8.40	14.8	5.22	72.62	53.8
22	-	669.4	51.9	8.0	0	9.60	30.4	5.25	35.90	47.5
31	1090	2123.7	52.2	29.6	1.7	9.50	7.0	4.83	86.81	59.1
32	-	130.3	5.2	29.9	14.7	0	50.2	.68	17.78	66.0

Exhibit 3: NURP Project BMP Sub-basins Land Use Profile

Exhibit 4

FOURCHE CREEK BASIN SOIL TYPES

Code	Soil Type
1	Ao - Amy silt loam, frequently flooded
2	Au - Amy - Urban land complex
3	CaC - Carnasaw Gravelly silt loam, 3 to 8 per cent slopes
4	CaD - Carnasaw gravelly silt loam 8 to 12 per cent slopes
5	CbC - Carnasaw - Urban land complex, 3 to 8 per cent slopes
6	CbD - Carnasaw - Urban land complex, 8 to 12 per cent slopes
7	CMC - Carnasaw - Mountainburg association, undulating
8	CMF - Carnasaw - Mountainburg association, steep
9	LdB - Leadvale - Urban land complex, 1 to 3 per cent slopes
10	LeB - Leadvale silt loam, 1 to 3 per cent slopes
11	Re - Rexor silt loam, frequently flooded
12	Rf - Rexor - Urban land complex, frequently flooded
13	SgB - Sallisaw gravelly silt loam, 1 to 3 per cent slopes
14	SgC - Sallisaw gravelly silt loam, 3 to 8 per cent slopes
15	ShC - Sallisaw - Urban land complex, 3 to 8 per cent slopes
16	SKC - Sallisaw - Leadvale association - undulating
17	UT - Urban Land

Assessments

Assessments completed during the three-year Fourche Creek study were of three types: (1) land use; (2) general water quality; (3) detailed water quality of BMP sites and assessment of pollutant loadings reductions.

A level two general land use study and soils study was performed of the entire Fourche Creek drainage basin at a scale of 1:20,000, and a far more detailed examination of land use, per cent imperviousness, and other parameters within the BMP test watersheds was completed at a scale of 1 :1,000. (Summary Exhibits 2-4.)

Water quality sampling and assessments during the first year of the project were general in nature and focused on defining the extent and nature of Fourche Creek pollutant levels system-wide. Eight sampling stations were located to yield a picture of Fourche water quality entering the metropolitan area and the impacts of tributaries draining the urban land uses. Coupled with the general water quality survey was a survey for the one-hundred-twenty-nine (129) toxics in which ten samples were analyzed for the presence of significant concentrations of metals, and organic compounds as part of the nationwide screening. (See Summary Exhibits 5-6.)

During the second and final years of the Fourche Creek project, water sampling efforts were concentrated in several test watersheds where BMP's were installed for evaluation.

After the initial assessment of the urban runoff impacts on Fourche Creek and its tributaries, the project studied the effectiveness of improved urban drainage systems and the parks as stream buffers to improve water quality.

(Urban) SITE 1040		Avg. value dry weather samples	Event Mean Concentration From Storm Events 10/17/80	11/14/80	2/1/81	5/17/81
BOD	mg/l	2.38	10.3	5.74	8.60	5.58
COD	mg/l	9.35	42.1	27.2	31.0	65.2
S.S.	mg/l	5.83	694	163	206	535
TKN	mg/l	0.61	1.45	1.50	1.36	1.54
TP	mg/l	0.171	0.268	0.173	0.422	0.41
Fe.coli		570	N/A	N/A	N/A	N/A

(Rural) SITE 1053		Avg. value dry weather samples	2/10/81	2/28/81	3/21/81	5/17/81
BOD	mg/l	2.82	4.76	2.90	2.24	1.91
COD	mg/l	11.5	8.47	44.6	16.5	29.7
SS	mg/l	3.96	49.0	58.4	12.3	91.0
TKN	mg/l	0.48	1.19	1.34	0.928	0.83
TP	mg/l	0.13	0.557	0.122	0.259	0.29
Fe.coli		487	N/A	N/A	N/A	N/A

(Mixed) SITE 1080		Avg. value dry weather samples	2/28/81	5/25/81	6/3/81
BOD	mg/l	2.4	2.02	N/A	N/A
COD	mg/l	14.7	3.16	25.8	30.6
SS	mg/l	15.0	12.8	12.0	16.5
TKN	mg/l	.69	1.79	0.81	0.90
TP	mg/l	.136	0.116	0.41	0.14
Fe.coli		185	N/A	N/A	N/A

Exhibit 5: NURP Storm vs. Dry Weather Sampling

RAINFALL EVENTS

	Amount	Duration
10/17/80	2.43	8 hrs. 44 min.
10/27/80	.80	13 hrs. 45 min.
11/14/80	3.32	19 hrs. 10 min.
12/ 8/80	1.73	14 hrs. 50 min.
1/ 6/81	.45	7 hrs. 47 min.
2/ 1/81	1.24	13 hrs. 20 min.
2/10/81	.79	9 hrs. 15 min.
2/28/81	1.52	17 hrs. 5 min.
3/21/81	1.79	16 hrs. 17 min.
4/18/81	.29	1 hrs. 58 min.
5/17/81	2.16	9 hrs. 30 min.
5/25/81	1.89	5 hrs. 46 min.
6/ 3/81	.92	3 hrs. 50 min.
6/30/81	2.15	7 hrs. 03 min.
10/23/81	2.08	19 hrs. 4 min.
11/22/81	.1	-
1/ 2/82	.62	12 hrs. 20 min.
1/22/82	2.35	2 hrs. 24 min.
1/29/82	.63	4 hrs. 42 min.
2/ 8/82	.83	6 hrs. 35 min.
2/16/82	.82	3 hrs. 55 min.
3/14/82	2.04	6 hrs. 49 min.
4/ 1/82	.09	1 hrs. 30 min.
4/ 2/82	4.44	19 hrs. 38 min.
4/18/82	.74	16 hrs. 33 min.
5/ 6/82	2.15	8 hrs. 47 min.
5/19/82	.96	2 hrs. 00 min.
10/28/82	1.04	4 hrs. 55 min.
11/19/82	1.29	15 hrs. 34 min.

Exhibit 6: NURP Precipitation and Duration Storm Events

Best management practices included retention basins, slope reduction, rock walls, and laid rock walls, and grassing at War Memorial Park (Coleman Creek), channel widening and straightening, grassing, and rip rap along Rock Creek, and installation of gabions with channel widening along Grassy Flat Creek. (See Summary Exhibits 7-9.)

Conclusions

The mean storm in the study area is .43 in. and lasts 48 hrs. at a rate of 0.09 inch/hour. The mean storm occurs every 76 hours. Ninety-seven per cent of the events have a return frequency at one year and less. Of the total storms 70% are less than the mean storm of .43 in. There are 27 storms per year greater than the average storm and less than the 1 year return frequency storm leaving 8 storms/year over the return frequency of one year.

Data from the Fourche Creek study showed water quality improvement on storms of 1 year return or less. Some data exist for longer return frequency storms, and the results are meaningful on about 92 to 97% of the storms which can be expected to occur. The one year storm intensity is approximately .1" per hour. The average storm above the 1 year frequency has an average intensity of 1.61" per storm.

Results of sampling at the Rock Creek and Coleman Creek sites are included in Summary Exhibit 10. The results show that both systems of BMPs are successful in removing pollutants from the runoff.

The BMP costs have been reduced to a $/pound per year and to a cost per square foot of drainage basin treated. The BMP at Rock Creek cost about 50% less per square foot than the Coleman Creek system, but both were effective in cost and size when comparing with the whole basin. The BMPs were between 0.2% and 0.4% of each drainage basin's total area. The Rock Creek System had a cost of $17.20 per linear foot. Even if land cost $10,000/ac, the cost would be $64 per linear foot, much less than $150/250-linear foot estimated for a complete concrete structure.

In the first year, analysis of data confirmed that urban runoff contributes to elevated pollutant levels in Fourche Creek, and demonstrate that there is a definite deterioration in water quality during storm events. (See Summary Exhibit 5.)

The water quality deteriorates as it passes through Little Rock except in the Fourche Creek bottoms, a wetlands section of the Creek, where the BOD, COD, and SS levels are reduced. However, conversely TKN and TP actually increase as the water passes through the bottoms. No significant toxics concentrations were found.

System-wide first year sampling showed that a large portion of the urban runoff problem in Little Rock is in large measure traceable to Rock Creek. It was decided to focus significant project efforts on this major tributary.

Evaluation in the second and third years of the project focused on verifying the effectiveness of the BMP's. It was found that sediment and BOD removal were effectively achieved at a reasonable cost as compared with other types of control practices. Temporary storage of water during storms resulting in a decline

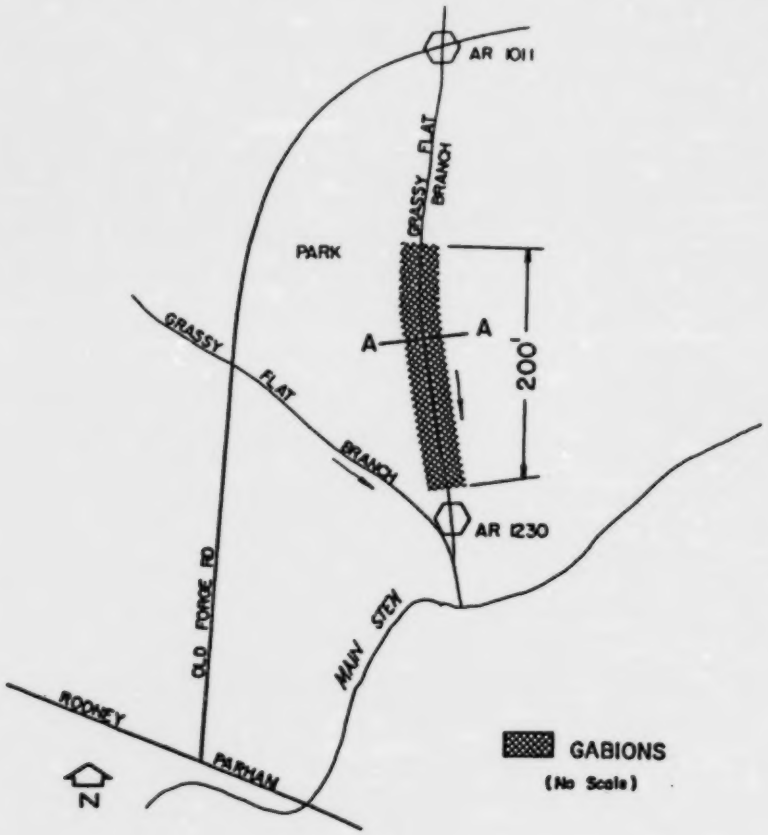
in the stream peak discharge was achieved with channel widening. Removals of Nitrogen and Phosphorous were not demonstrably cost effective as a primary consideration. (See Summary Exhibit 10.)

Analysis of the effectiveness of the BMP's showed that gabions were very effective in stabilizing eroding banks and are especially useful where vertical channel sides should be maintained. This is helpful where easements do not permit slope reduction measures. Gabions also permitted biological activity to continue on stream banks, unlike sterile concrete walls, which do not provide soil pockets. Costs of installation were modest compared with concrete channel solutions, the chief drawback to gabions being the difficulty of installation for inexperienced crews. (Summary Exhibit 7.)

Channel widening and straightening along Rock Creek was completed at minimal cost and proved effective in decreasing erosion by slowing water velocity and provided some significant water retention as banks acted as storage areas. This latter action effectively shaved the peak flow of water through the area and provided downstream relief. Grassing of banks, slope reduction and rip rap stabilization of turns and side channels yielded effective and inexpensive controls on erosion. (Summary Exhibit 8.)

At War Memorial Park the most expensive work was performed. Here additional costs resulted from aesthetic requirements which arise from building hand-laid rock walls and rock-faced dams. However, the BMP's were very effective in stopping erosion in the narrow channels and in removing BOD and other pollutants. The

GRASSY FLAT BRANCH



CREEK SECTION A-A

BEFORE GABIONS INSTALLED

AFTER GABION IMPROVEMENT

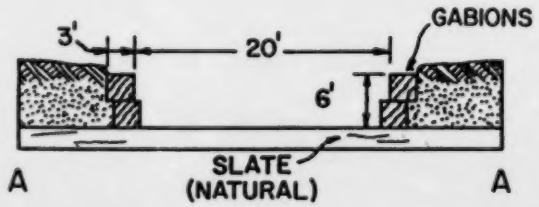
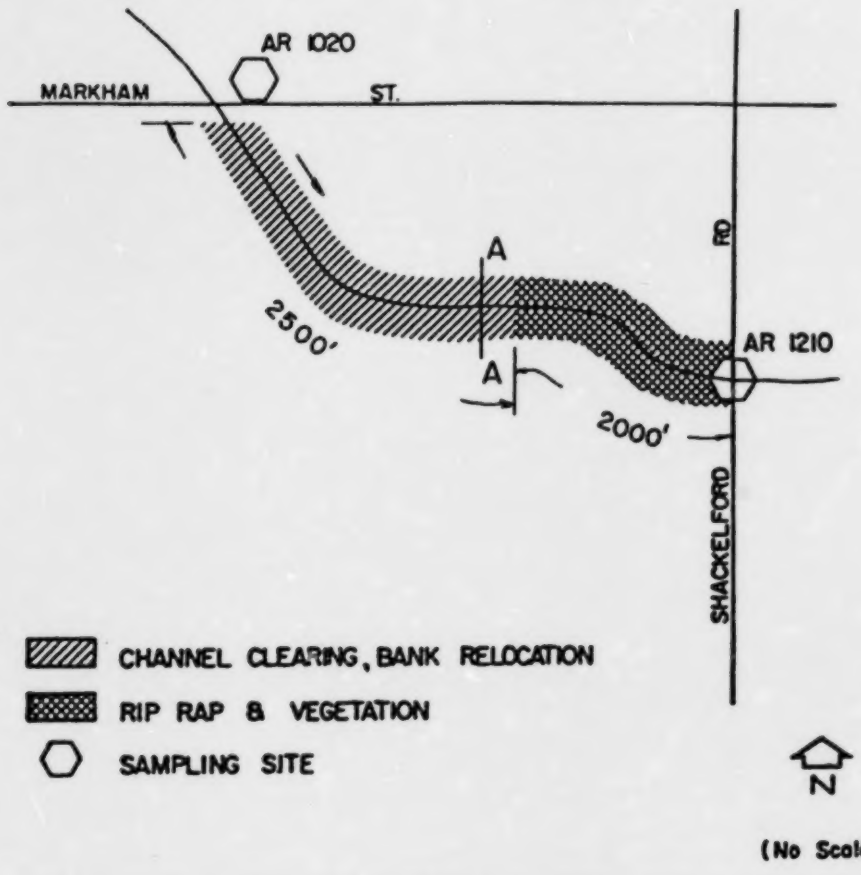


Exhibit 7

STABILIZATION OF ROCK CREEK



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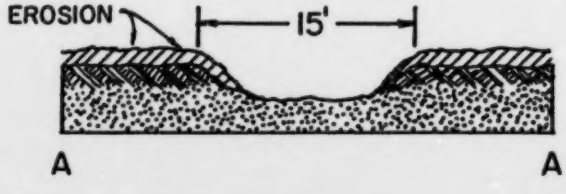
CREEK SECTION A-A

BEFORE IMPROVEMENTS



AFTER IMPROVEMENTS

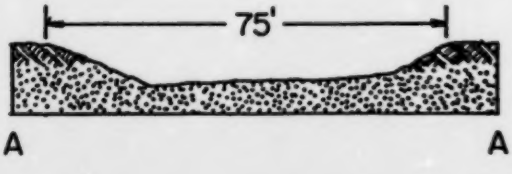
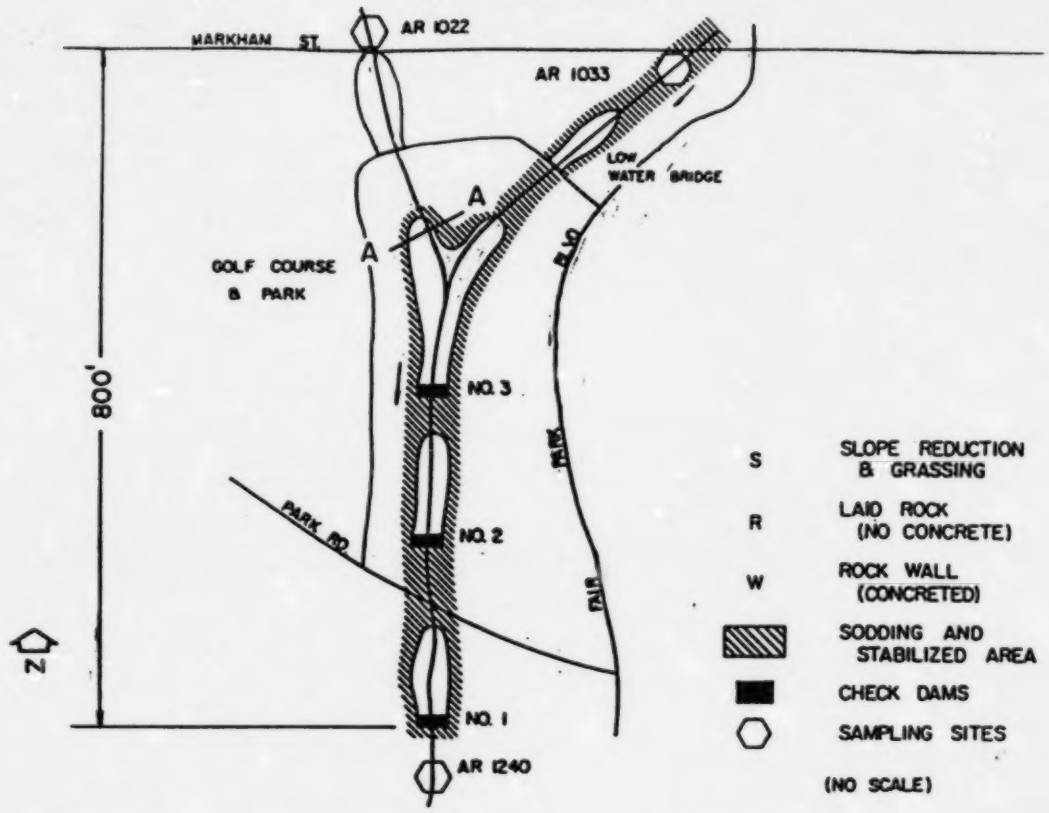


Exhibit 8

SODDING AND CATCH BASINS

WAR MEMORIAL PARK



CREEK SECTION A-A

BEFORE IMPROVEMENTS

E = EROSION

AFTER IMPROVEMENTS

S = SLOPE REDUCTION
G = GRASSING

Exhibit 9

Exhibit 10

Table 1-A

Summary of Storm Event
Coleman Creek

January 2, 1982

	AR 1033 RB	AR 1022 LB	AR 1240 DS	Reduction (lbs)	Reduction %
BOD	1,814	454	1,641	627	28%
SS	17,291	11,358	27,586	1,063	4%
TN	237	81	252	66	21%
TP	100	41	81	60	43%
VOL (MG)	23.58	5.04	16.5		42%

Table 1-B

Coleman Creek

November 11, 1981

BOD	1,250	332	885	697	44%
SS	42,025	14,407	33,509	22,923	41%
TN	353	108	247	214	46%
TP	98	48	102	44	30%
VOL	16.53	5.59	14.26		36%

AR 1033 - Right branch of Coleman Creek upstream of BMP

AR 1022 - Left branch of Coleman Creek upstream of BMP

AR 1240 - Downstream of BMP's Coleman Creek

Exhibit 10 (cont'd)

Table 1-C

Coleman Creek

October 23, 1981

	AR 1033 RB	AR 1022 LB	AR 1240 DS	Reduction (lbs)	Reduction %
BOD	1,913	50	1,388	575	29%
SS	10,806	576	13,273	-1,792	-16%
TN	428	11	253	186	42%
TP	121	3	81	43	35%
VOL (MG)	40.18	1.16	29		30%

Exhibit 10

BMP SITE ROCK CREEK

STORM EVENT

Removal in % of Pounds

	January 22, 1982	November 19, 1982
BOD	27%	20%
SS	30%	58%
TKN	-18%	22%
TP	-16%	49%
CU	NA	26%
ZN	NA	23%
FE	NA	-.22

ROCK CREEK

STORM EVENT

November 19, 1982

BMP SITE

	Up Stream	Down Stream	% Removal AS (EMC)
BOD	6.12	6.4	-5%
SS	202	153	24%
TKN	1.71	1.75	-3%
TP	.212	..140	34%
CU	.025	.021	1.6%
ZN	.02	.02	-
FE	4.02	4.05	-.7%

Exhibit 11

NURP ANALYSIS FOR ROCK CREEK AND COLEMAN CREEK

COSTS

	Rock Creek	Coleman Creek
REMOVAL OF --- BOD	316	633
IN LB, SS	20,812	7,000
TKN	96.5	150
TP	53.2	50
THERE ARE 27 STORMS PER YEAR WITH .43 IN/STORM		
BOD	8,532	17,091
SS	561,924	189,000
TKN	2,605.5	4,050
TP	1,436.4	1,350
TOTAL COST FOR LABOR AND MATERIALS		
	$67,000	$40,000
COST PER POUND OF REMOVAL		
BOD	7.8528	2.3404
SS	.11923	.21164
TKN	25.715	9.8765
TP	46.644	29.630
20 YR. NO INTEREST COST/YR PER-LB		
BOD	.39264	.11702
SS	.00596	.01058
TKN	1.2857	.49383
TP	2.3322	1.4815
DRAINAGE AREA- IN AC. ---	4,700	980
COST PER ACRE (TOTAL LABOR & MATERIALS)		
BOD	.00167	.00239
SS	2.5-5	2.2-4
TKN	.00547	.01008
TP	.00992	.03023

combination of grassing, slope reductions, channel armoring, and retention basins created an attractive addition to the park and at the same time demonstrated that pollutant removal can be effected significantly in even small, urban streams where large retention basins are not possible. (See Summary Exhibit 9.)

Several general conclusions were reached during the three-year Fourche Creek Urban Runoff Project.

(1) Elevated coliform measurements are the result of leaking and overflowing sewers and expected runoff from densely populated areas;

(2) The urban drainage system may be adapted to provide effective treatment of area streams;

(3) BOD, TKN, TP, and TSS are expensive to remove effectively unless included as anincremental cost of flood control projects;

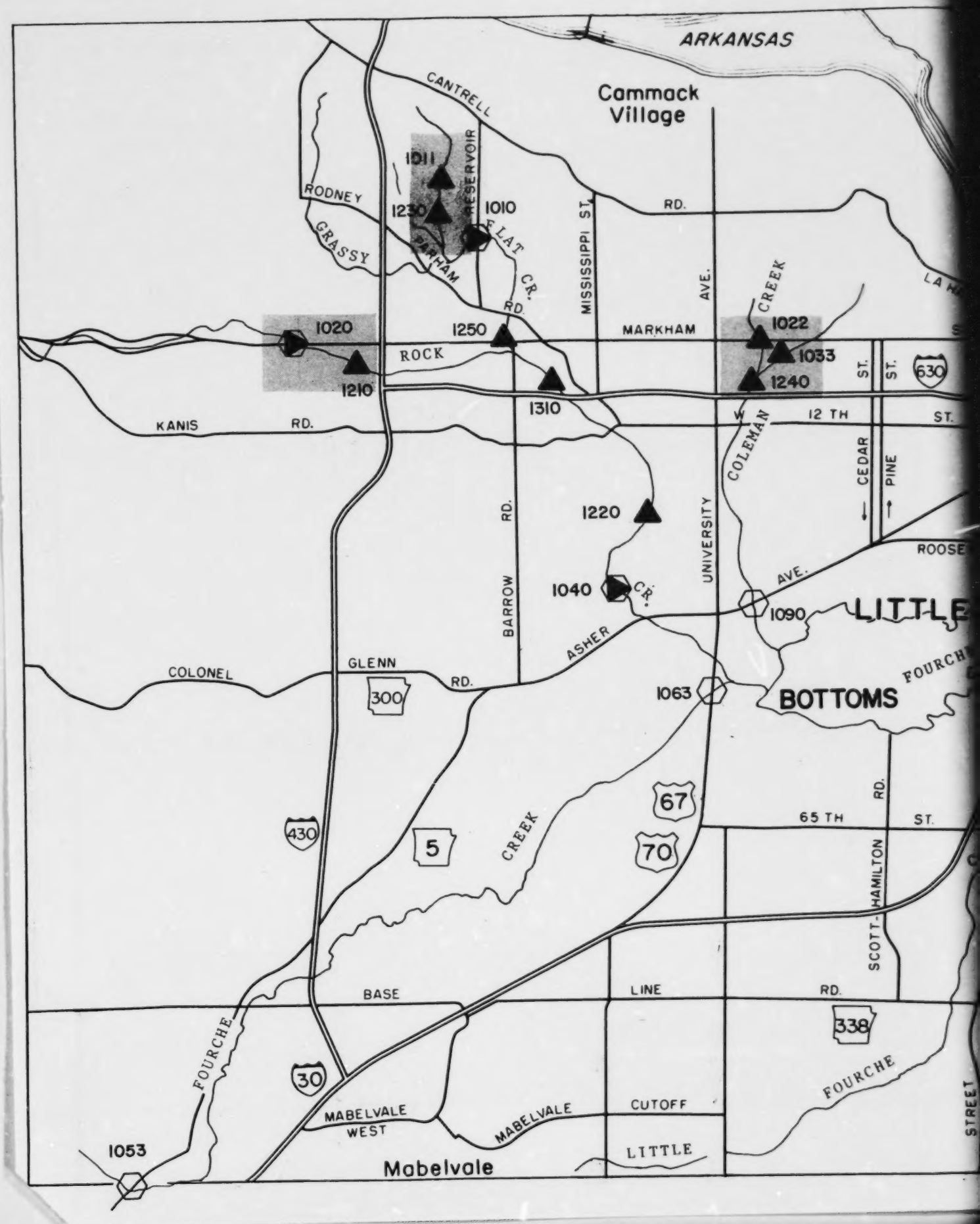
(4) Stormwater management should incorporate grassed drainage ways and settling basins;

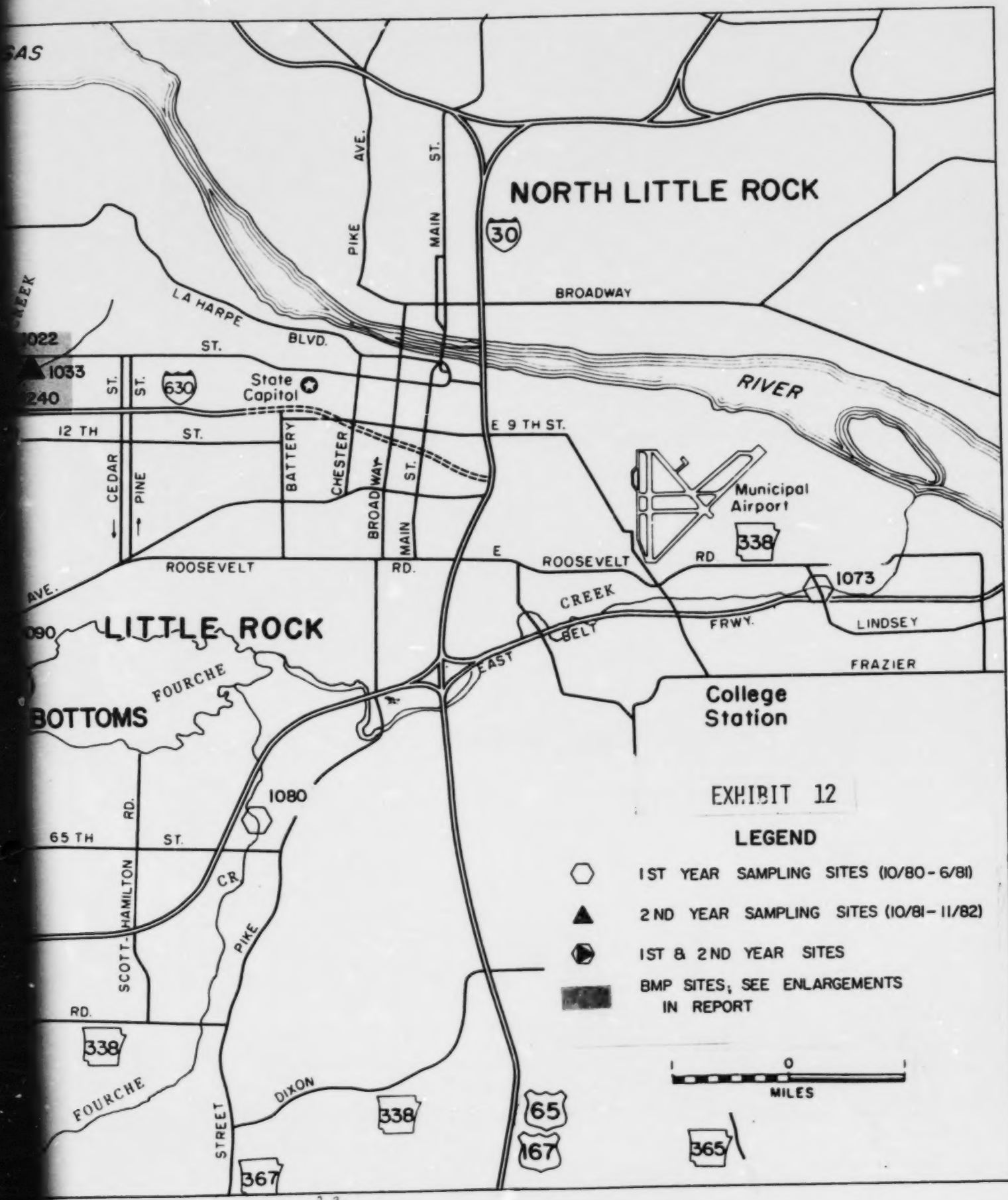
(5) A functional urban drainage system which improves water quality will be one which incorporates grassing and other natural simulation techniques and avoids extensive use of concrete drainage ways.

(6) A "piggyback" principle must be adopted to realize implementation of urban runoff controls. Water quality improvement goals must be harnessed to flood reduction issues,

and aesthetic considerations may be secondary but tied to water quality management considerations.

Thus in Little Rock at least, public and local officials will most strongly, and perhaps only, support water quality improvement practices which are multi-purpose, incorporating pollution controls with flood reduction and park enhancement objectives.


ARKANSAS
Cammack Village
CANTRELL
RODNEY
GRASSY
PARHAM
RESERVOIR
FLAT CR.
1011
1230
1010
RD.
MISSISSIPPI ST.
AVE.
CREEK
1022
1033
1240
MARKHAM
1020
1250
1210
ROCK
1310
KANIS
RD.
12 TH
ST.
COLEMAN
CEDAR
PINE
630
1220
BARROW
RD.
UNIVERSITY
1040
CR.
AVE.
1090
LITTLE
ROOSE
ASHER
COLONEL
GLENN
RD.
300
1063
BOTTOMS
FOURCH
67
65 TH
ST.
430
5
CREEK
70
SCOTT-HAMILTON
RD.
BASE
LINE
RD.
338
FOURCHE
30
MABELVALE
WEST
MABELVALE
CUTOFF
1053
LITTLE
Mabelvale
STREET


NORTH LITTLE ROCK
LITTLE ROCK
BOTTOMS
College Station
PIKE AVE.
MAIN ST.
BROADWAY
LA HARPE BLVD.
ST.
State Capitol
RIVER
E 9 TH ST.
12 TH ST.
CEDAR
PINE
BATTERY
CHESTER
BROADWAY
MAIN ST.
Municipal Airport
ROOSEVELT RD.
E ROOSEVELT RD
CREEK
BELT FRWY.
LINDSEY
FRAZIER
EAST
FOURCHE
65 TH ST.
SCOTT-HAMILTON RD.
CR PIKE
RD.
FOURCHE
DIXON STREET
1033
1022
240
1080
1073
090
30
630
338
65
167
367
365
EXHIBIT 12
LEGEND
1ST YEAR SAMPLING SITES (10/80 - 6/81)
2ND YEAR SAMPLING SITES (10/81 - 11/82)
1ST & 2ND YEAR SITES
BMP SITES, SEE ENLARGEMENTS IN REPORT
0
MILES